SMART GRID INTEROPERABILITY PANEL

SPRING 2012 FACE-TO-FACE
CHARLOTTE, NC

USE CASE FOR THE TRANSMISSION BUS LOAD MODEL (TBLM)

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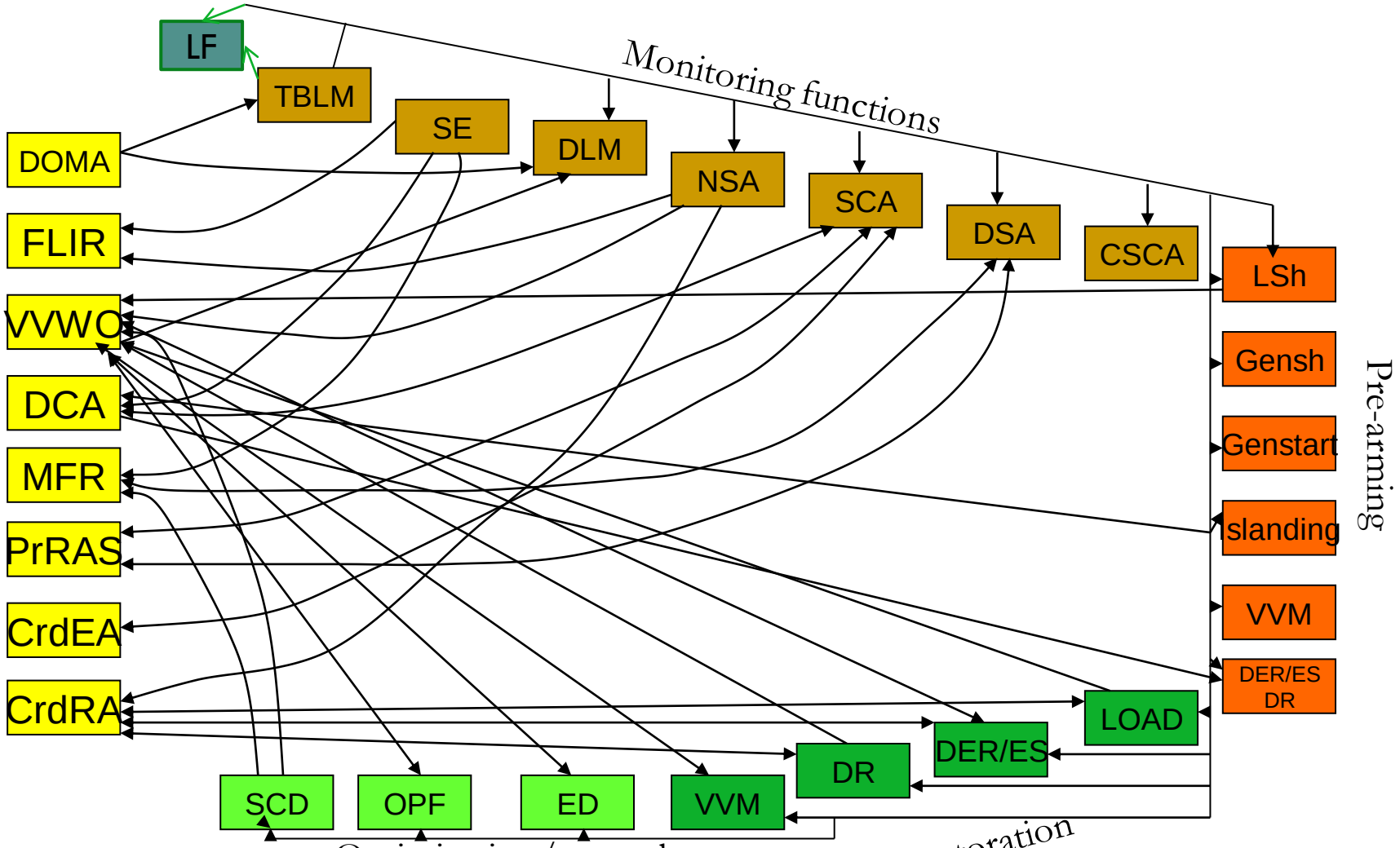
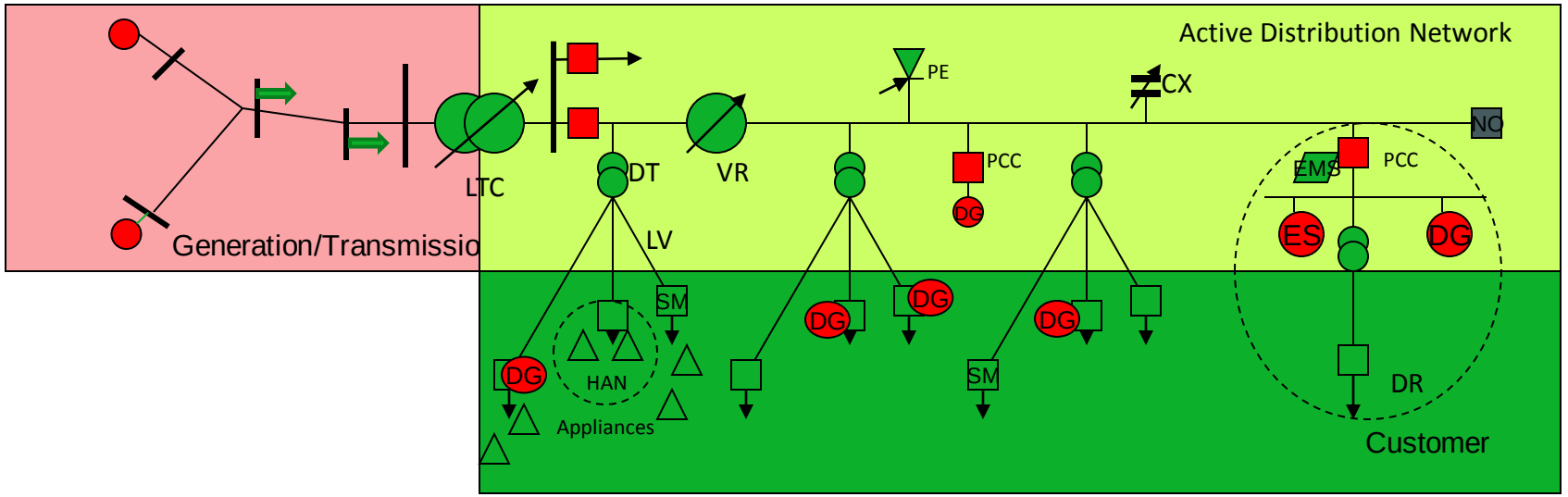
Interrelationships between DMS and EMS functions (non-exhaustive)

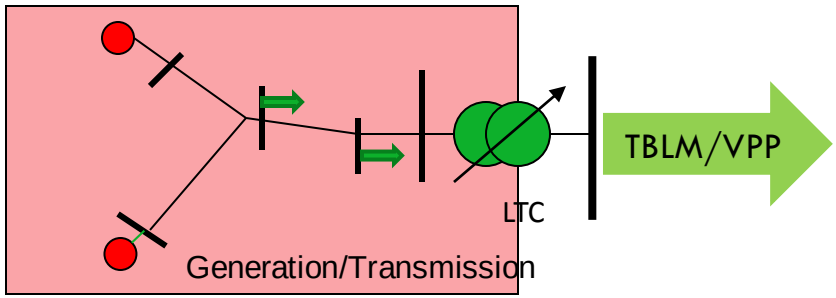


How to Exchange Information between T&D?

- It is unrealistic to expect that the monitoring and control of transmission operations will reach out to every device and every function in the distribution and customer domains.
- The T/D buses of the near-real time model of transmission operations are the demarcation points between transmission and distribution domains.

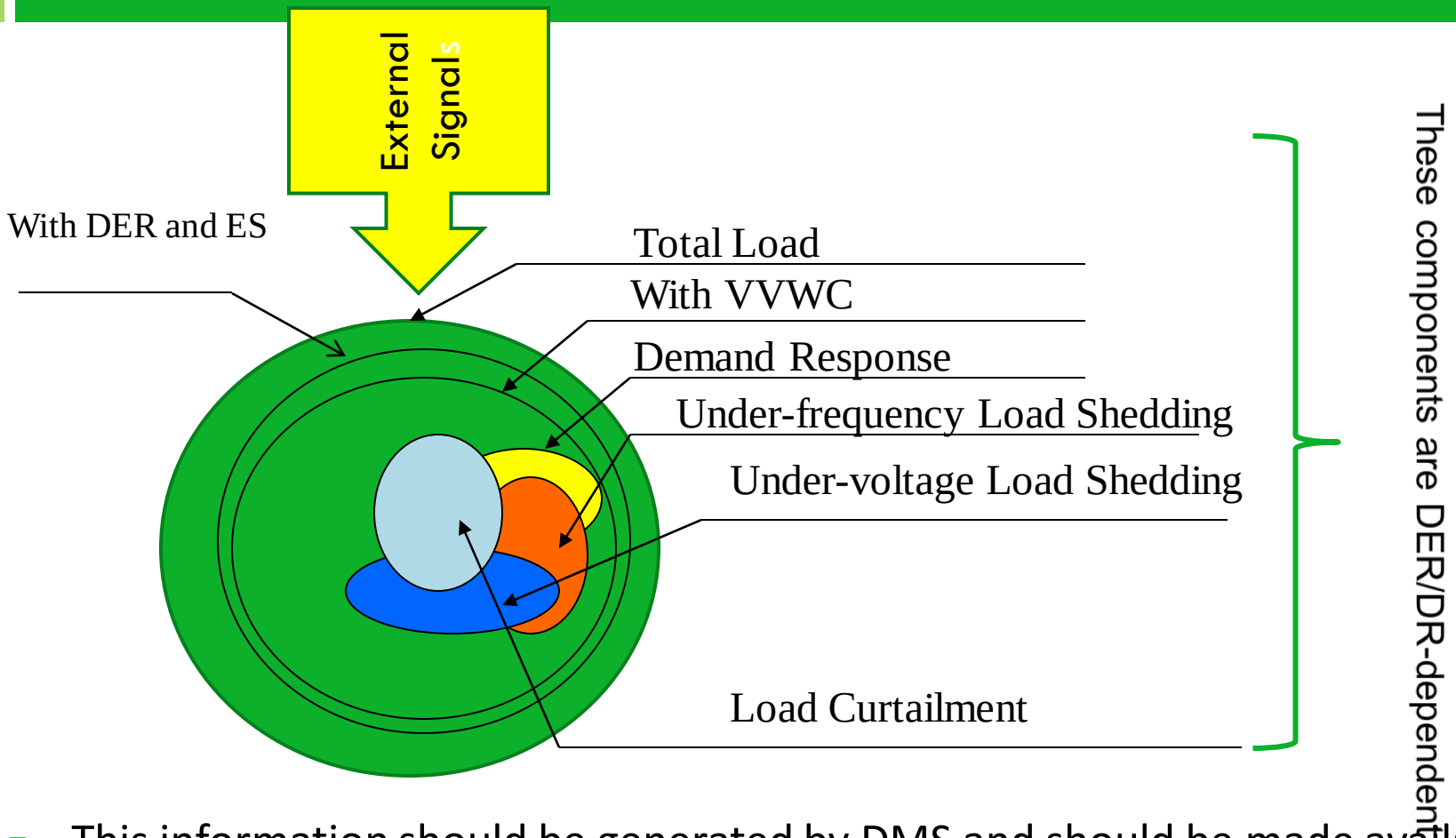
Transmission Bus Load Model (TBLM) Concept





It is suggested aggregating the capabilities and the dynamic of distribution operations in TBLM

Load Model is a Component of TBLM

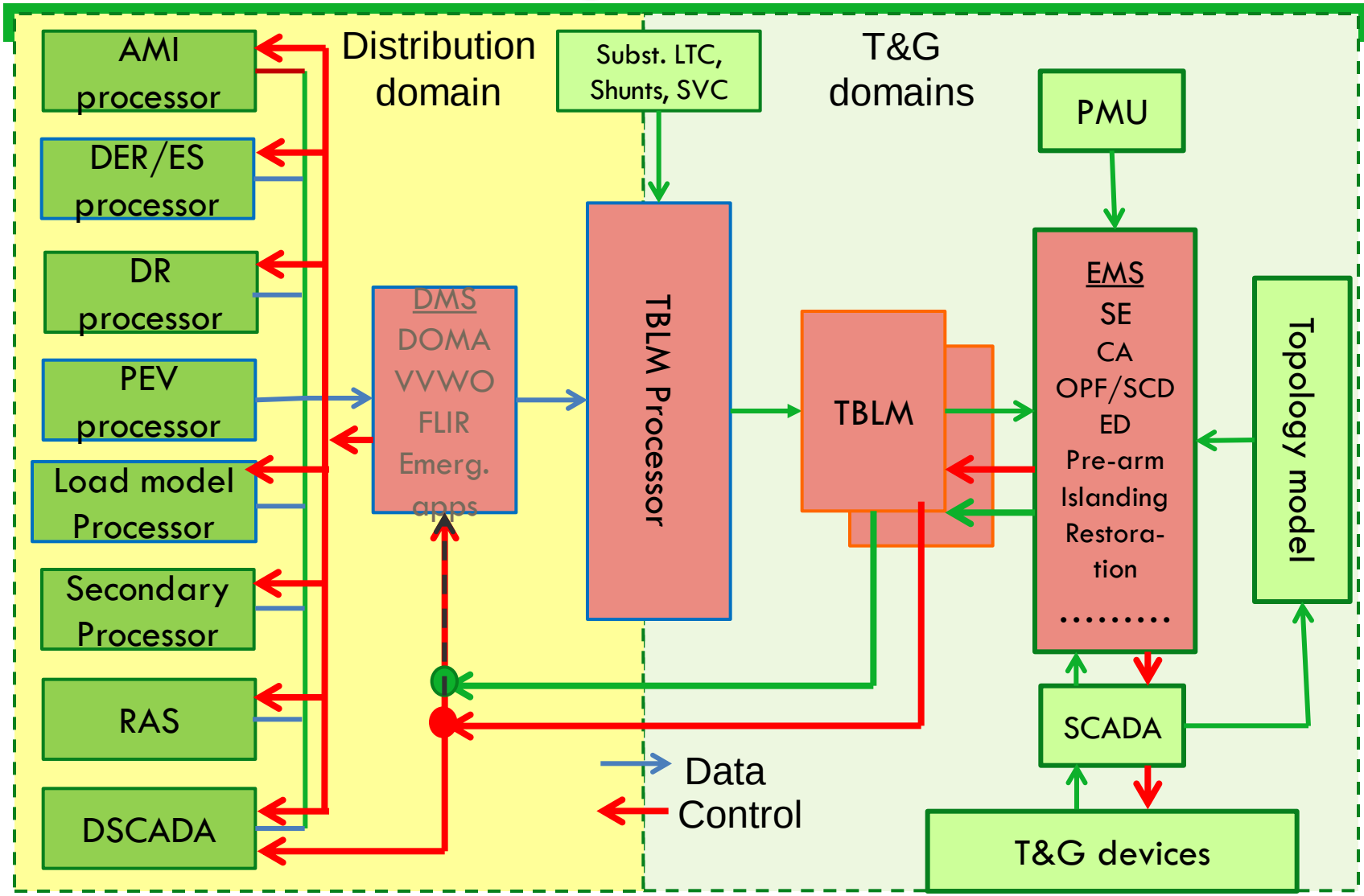


- This information should be generated by DMS and should be made available to EMS

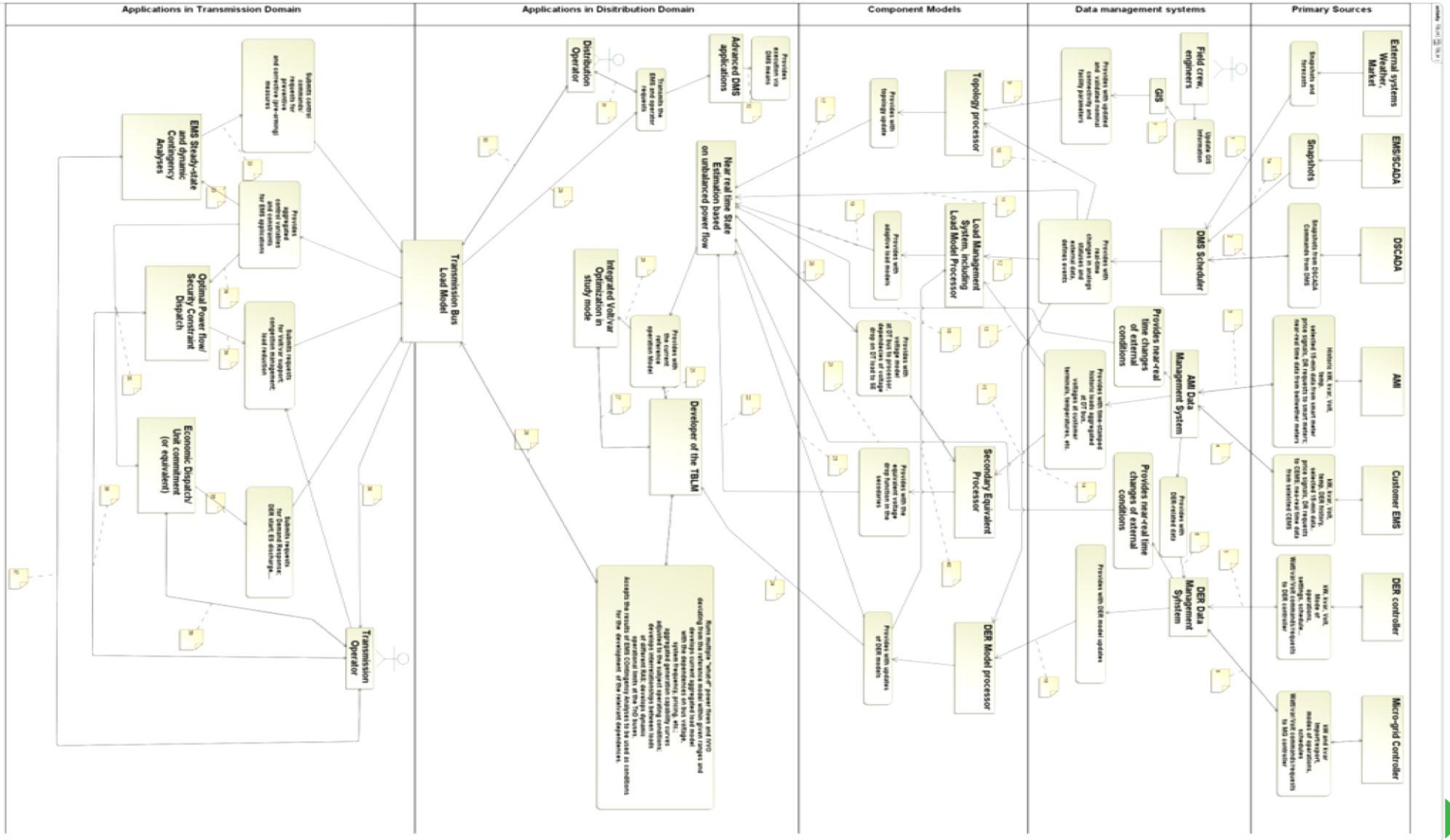
Other Components of TBLM

- Aggregated capability curves
- Aggregated real and reactive load-to-voltage dependencies
- Aggregated real and reactive load-to-frequency dependencies
- Aggregated real and reactive load dependencies on
  - Demand response control signals,
  - Dynamic prices,
  - Weather, etc.
- Aggregated dispatchable load
- Model forecast
- Overlaps of different load management functions, which use the same load under different conditions.
- VPP technical and economic functions and attributes
- Degree of uncertainty…..

Information Exchange between T&D Domains



Activity Diagram of Use Case for TBLM support



Scenarios for TBLM Use Cases

1. Develop aggregated DER capability curves for TBLM
2. Develop aggregated model of dispatchable load for TBLM
3. Develop aggregated real and reactive load-to-voltage dependencies
4. Develop aggregated real and reactive load-to-frequency dependencies
5. Develop aggregated real and reactive load dependencies on Demand response control signals
6. Develop aggregated real and reactive load dependencies on dynamic prices,
7. Adapt aggregated real and reactive load dependencies to weather conditions, etc.
8. Develop aggregated real and reactive load dependencies on ambient conditions.
9. Develop models of overlaps of different load management functions, which use the same load under different conditions.
10. Assess the degree of uncertainty of TBLM component models

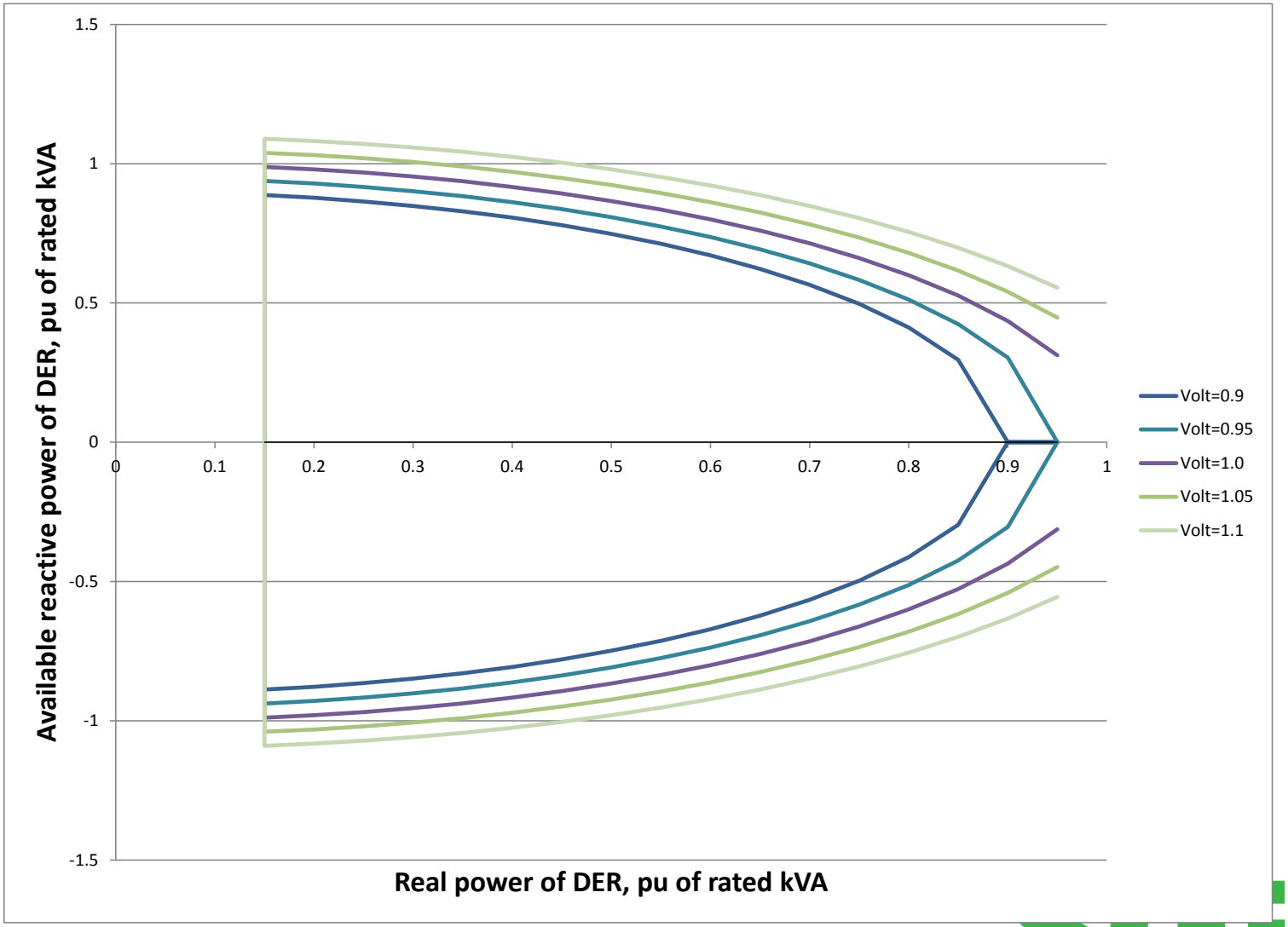
Scenario categories 1 and 2

- Develop aggregated DER capability curves for TBLM
- Develop aggregated model of dispatchable load for TBLM

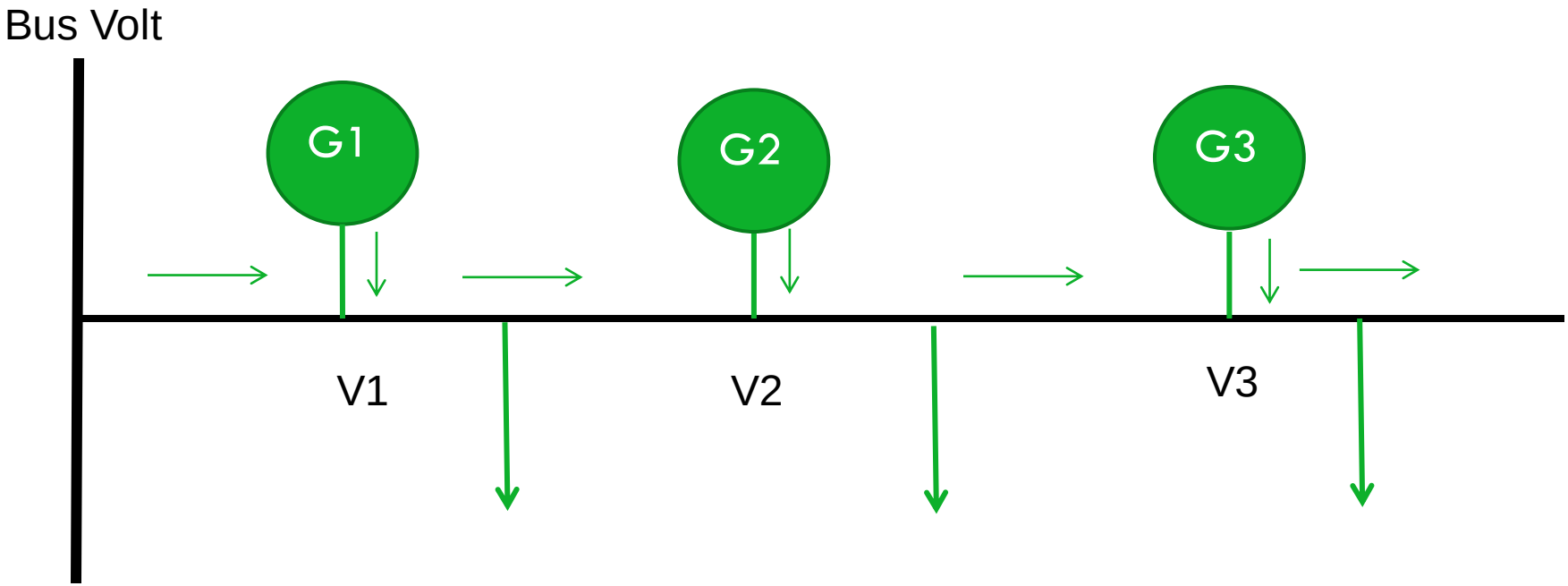
Objectives

- Provide near-real-time aggregated capability curves of DER in the TBLM for EMS applications
- Provide near-real-time aggregated real and reactive dispatchable load in distribution in the TBLM for EMS applications
  - Based on DER only
  - Based on DER and DR

DER capability curves
kvar=f(kW and Volt)

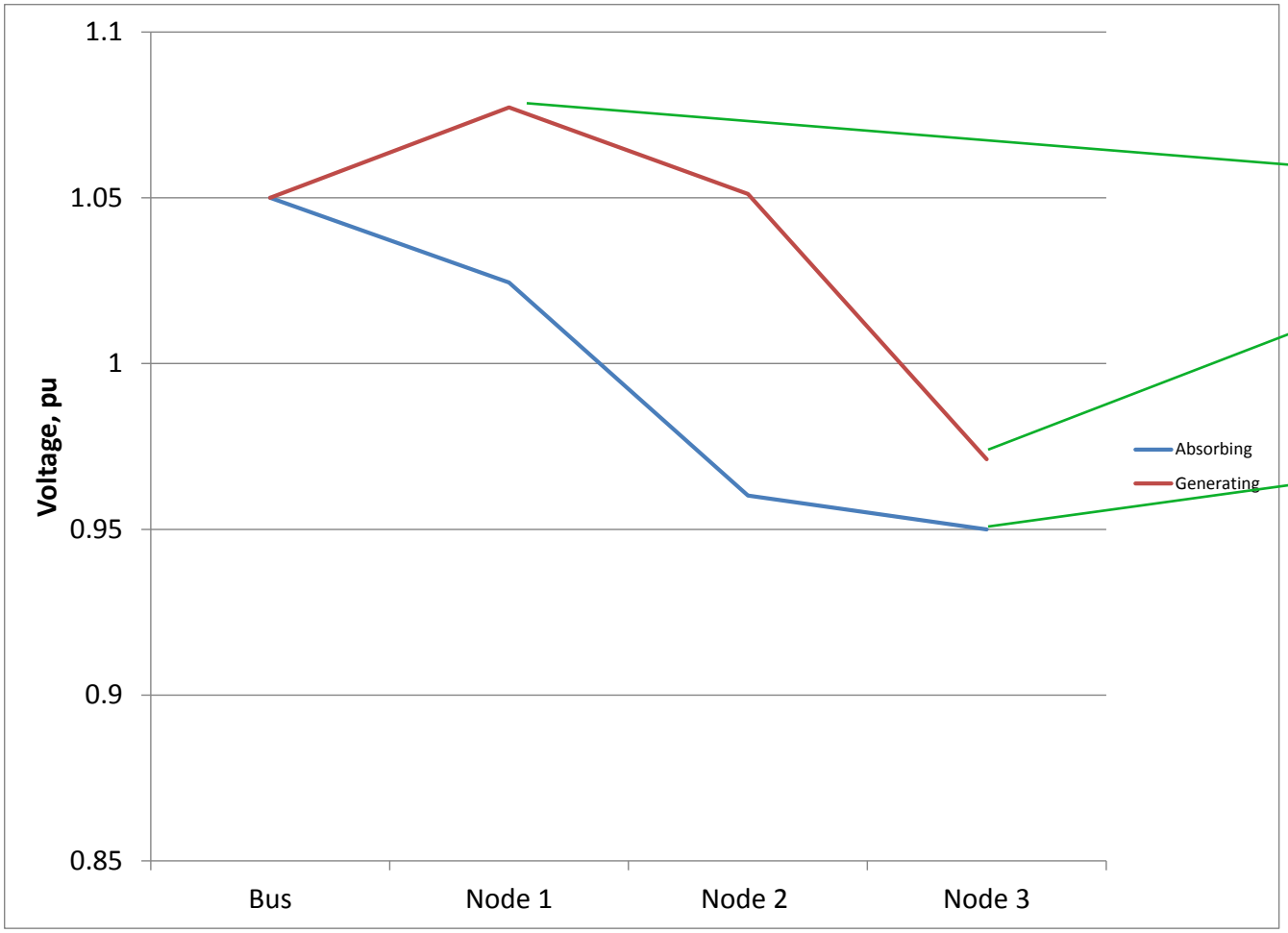


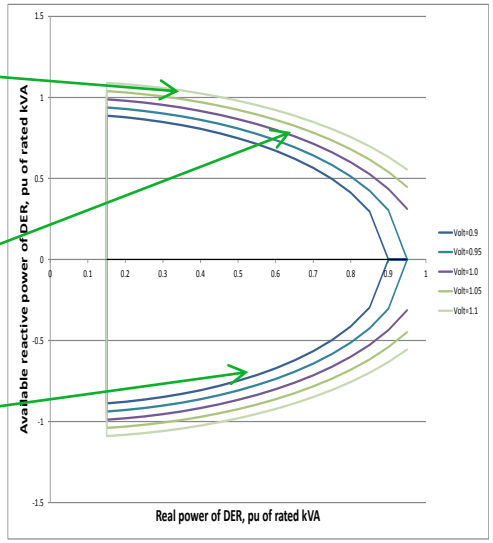
The actual voltages are different at different PCCs



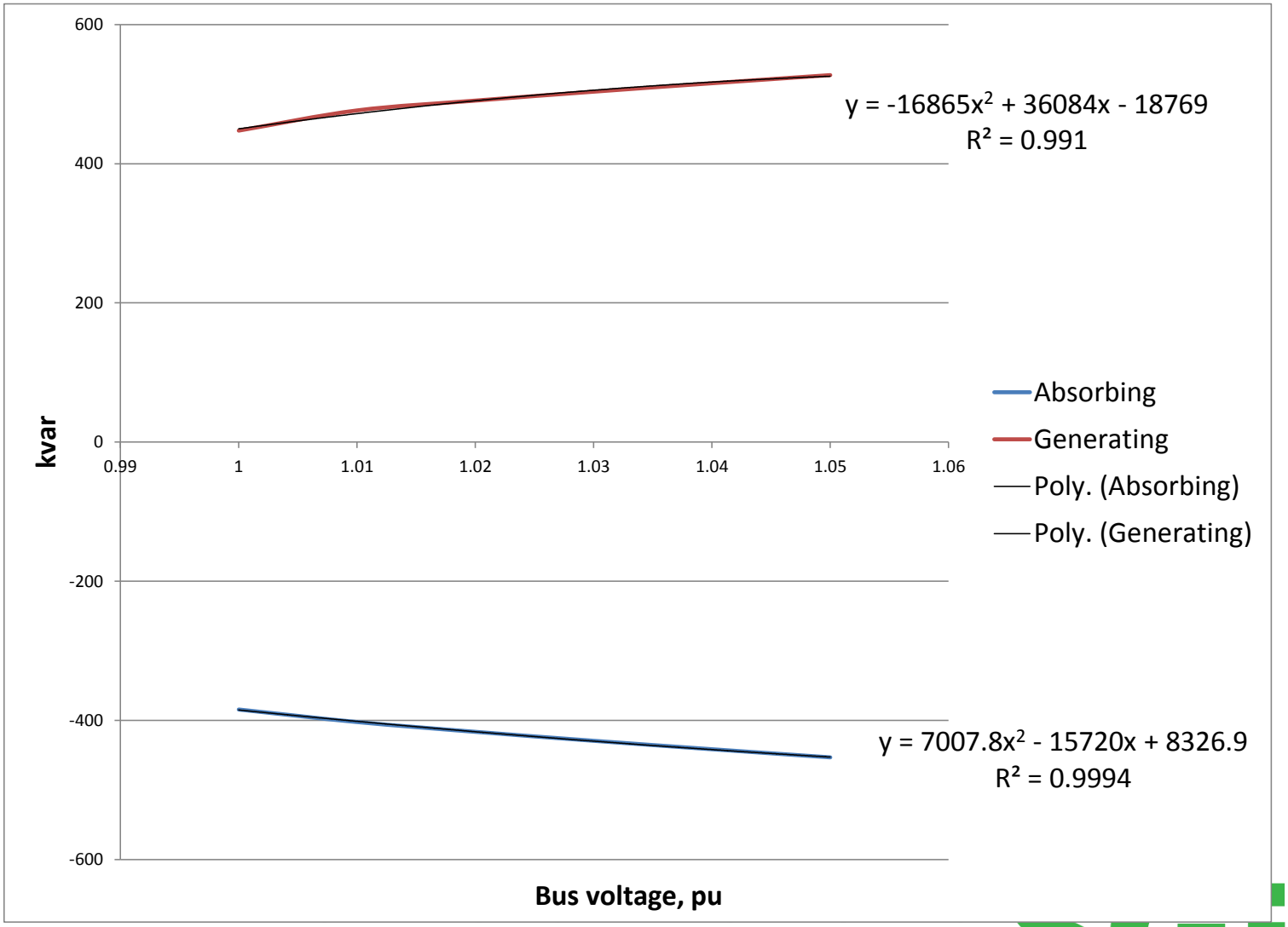
The voltage at PCC depends on the substation bus voltage, distribution parameters and power flow,
and on the operations of DER

Voltage profile along feeder with DER in different modes.

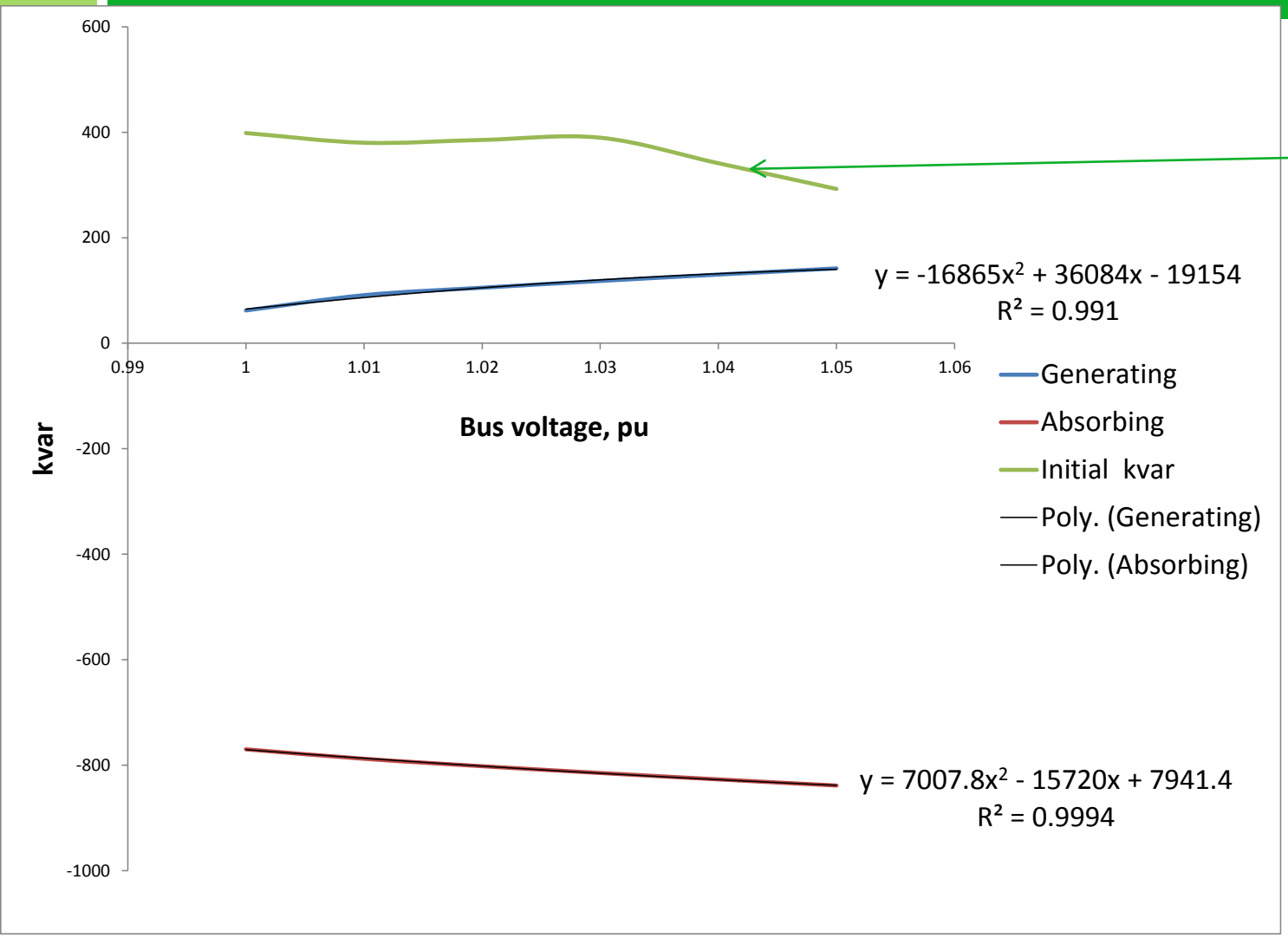


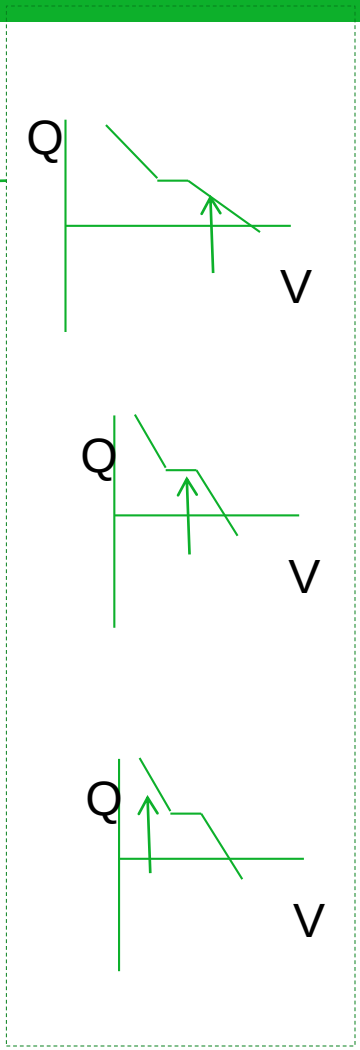


Near-real-time aggregated capability curves in the TBLM



Dispatchable aggregated reactive load in the TBLM





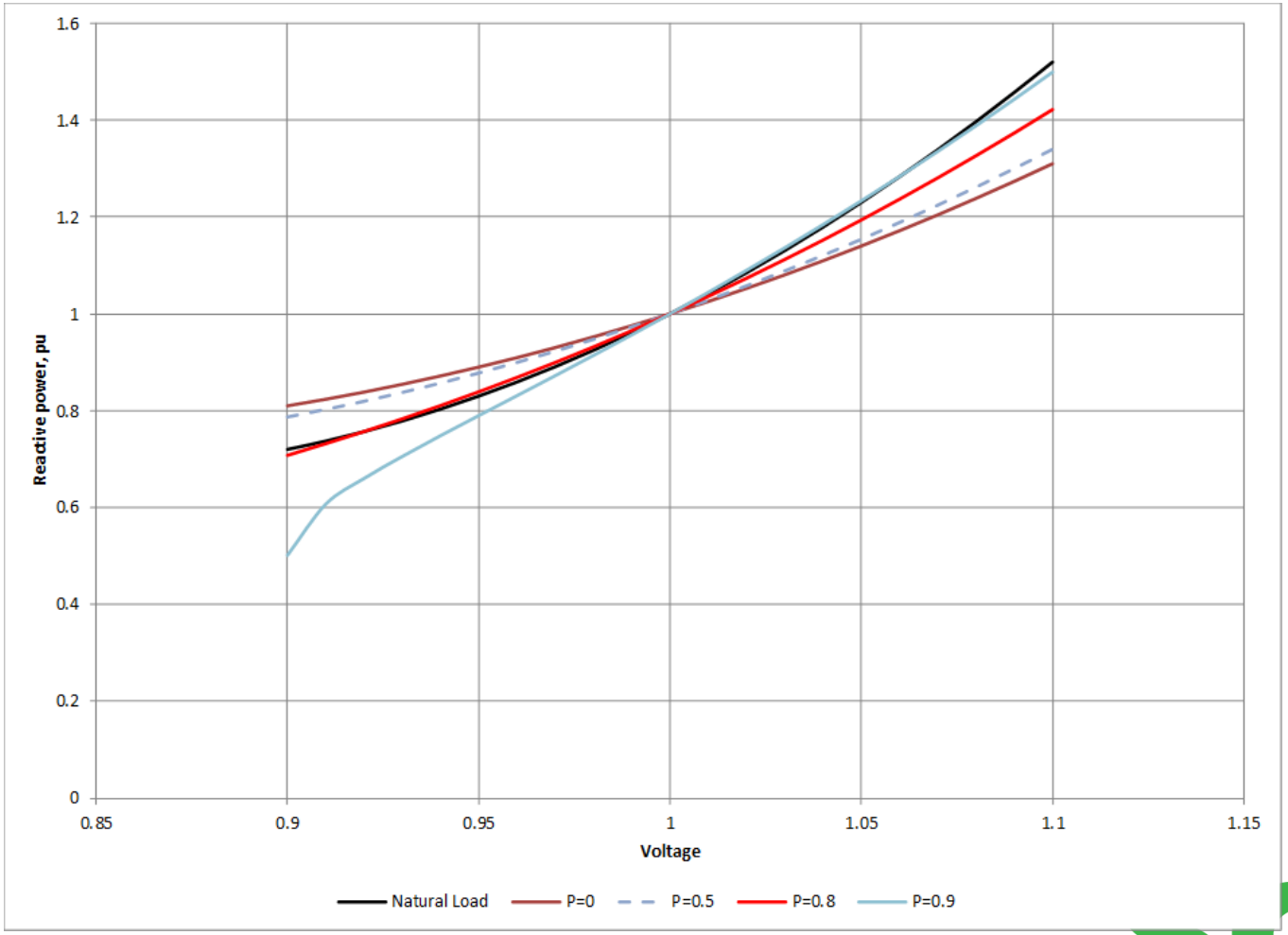
Input data for development of aggregated capability curves and dispatchable loads

- Actual kW and voltages at DER PCCs
  - Sources of information:
    - DSCADA
    - DER Data Management System
    - DOMA
- Voltages at DER PCCs under different bus voltages
  - Sources of information:
    - DOMA
- Modes and settings of DER Volt/var functions
  - Sources of information:
    - DSCADA
    - DER Data Management System

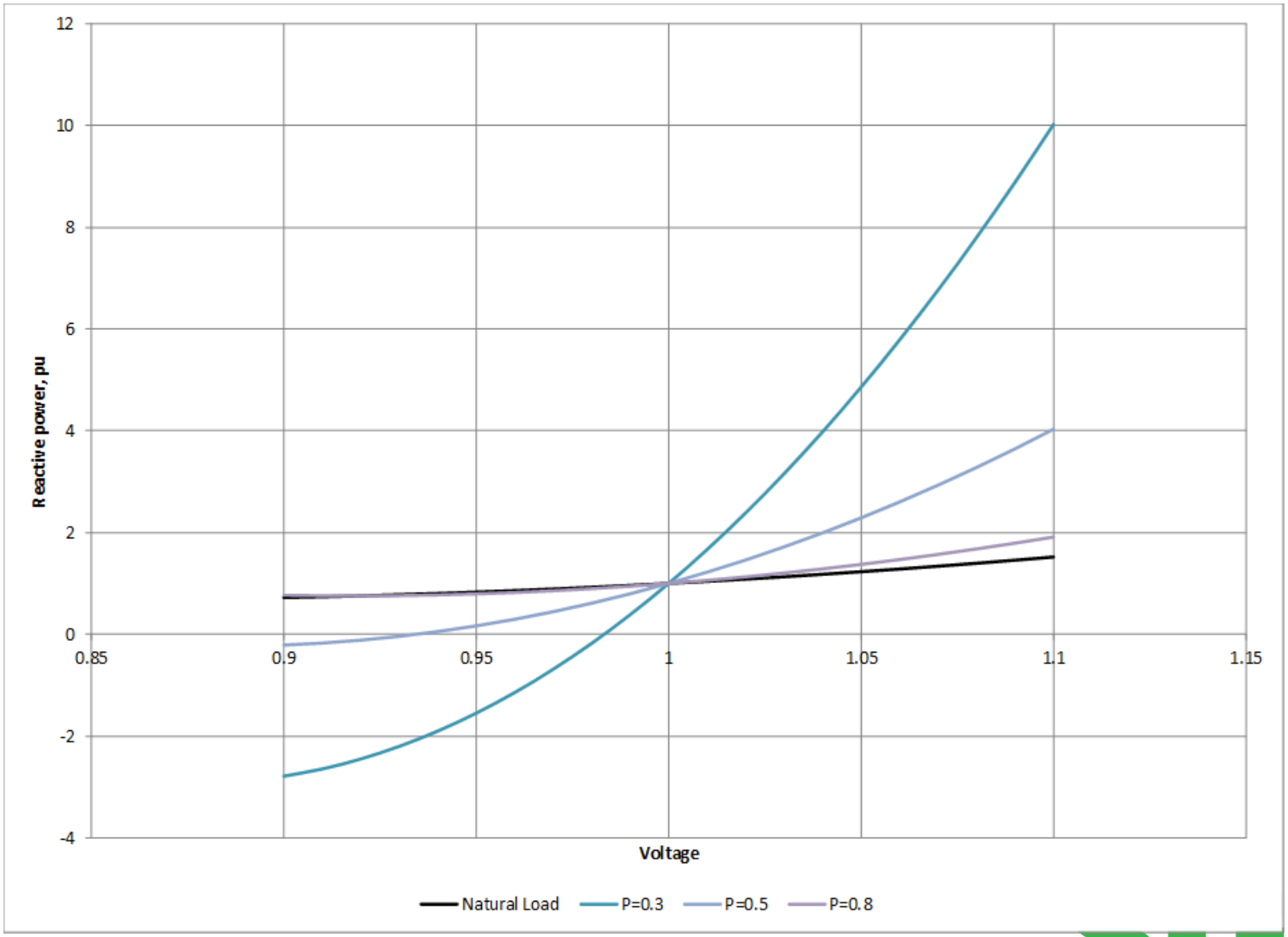
Aggregated real and reactive load-to-voltage and to frequency dependencies

- *The load-to-voltage dependencies should cover the normal and the emergency voltage and frequency ranges*
  - Aggregated immediate real and reactive load-to-voltage dependencies in the TBLM for the dynamic EMS applications (up to seconds)
  - Aggregated steady-state real and reactive load-to-voltage dependencies (up to several hours)

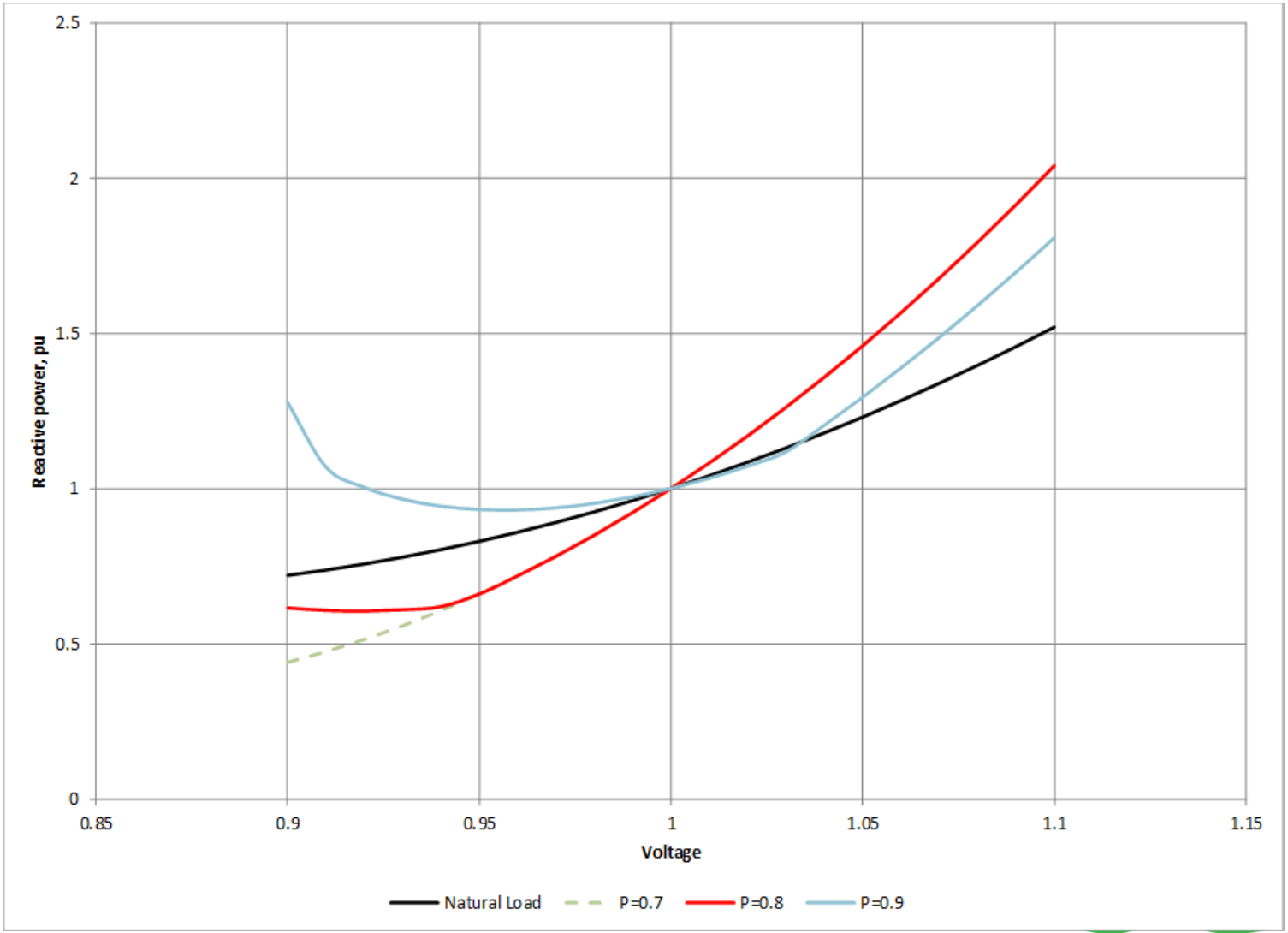
Reactive load-to-voltage dependency with embedded PV DER in maximum inductive mode



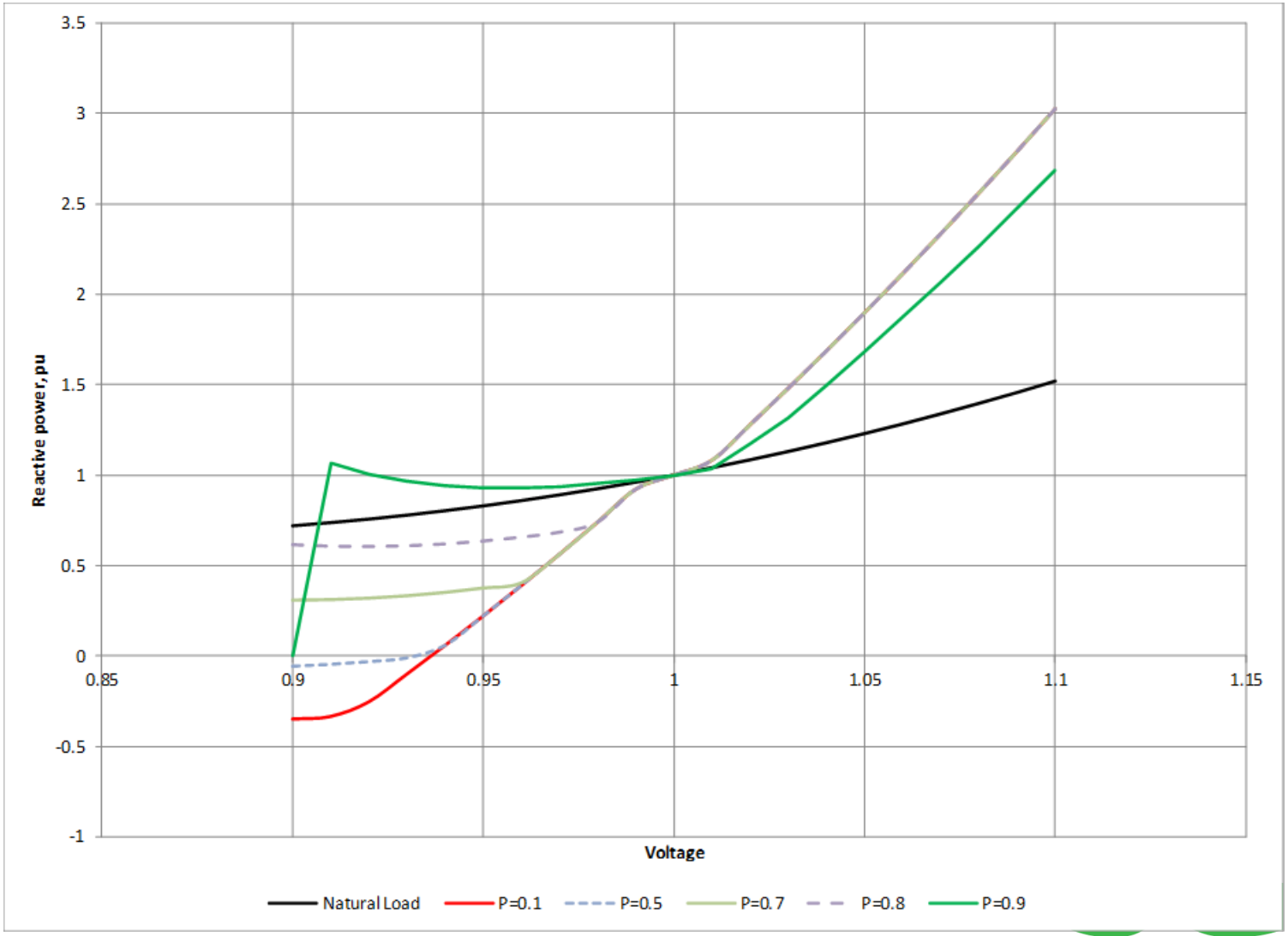
Reactive load-to-voltage dependency with embedded PV DER in maximum capacitive mode



Reactive load-to-voltage dependency with embedded PV DER in constant Q mode

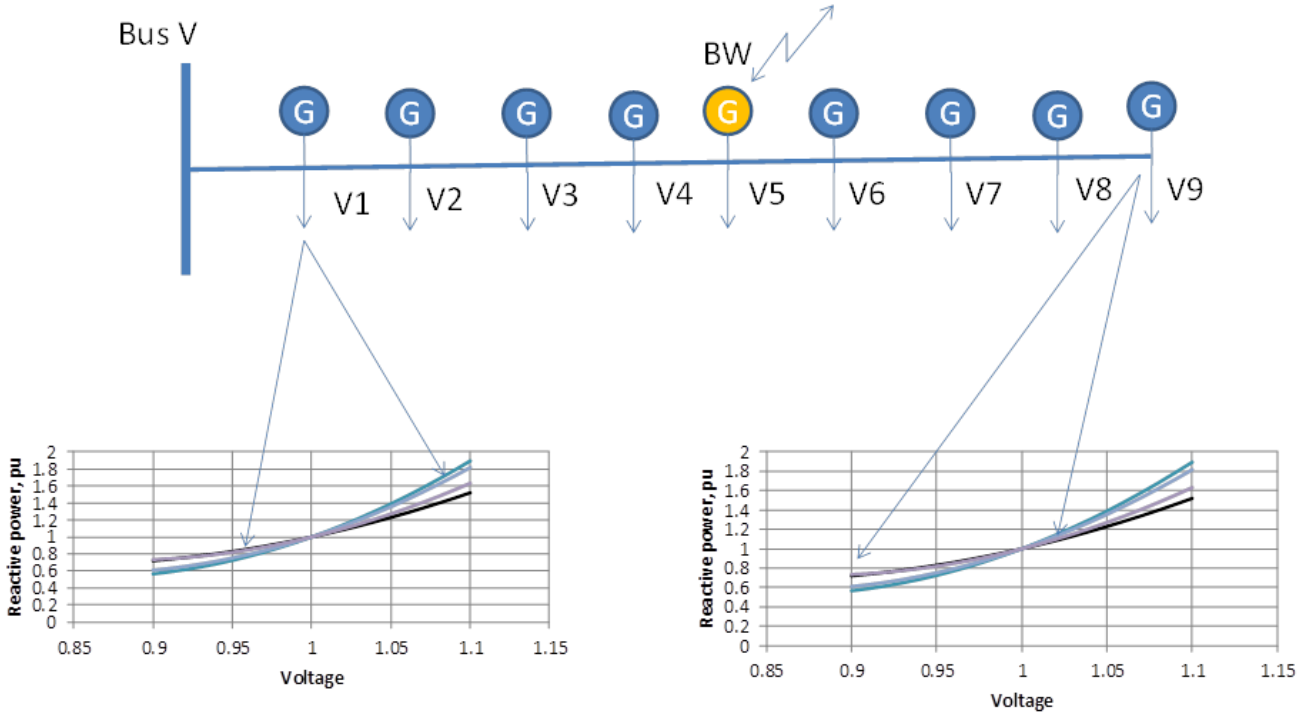


Reactive load-to-voltage dependency with embedded PV DER in constant Q mode with voltage override

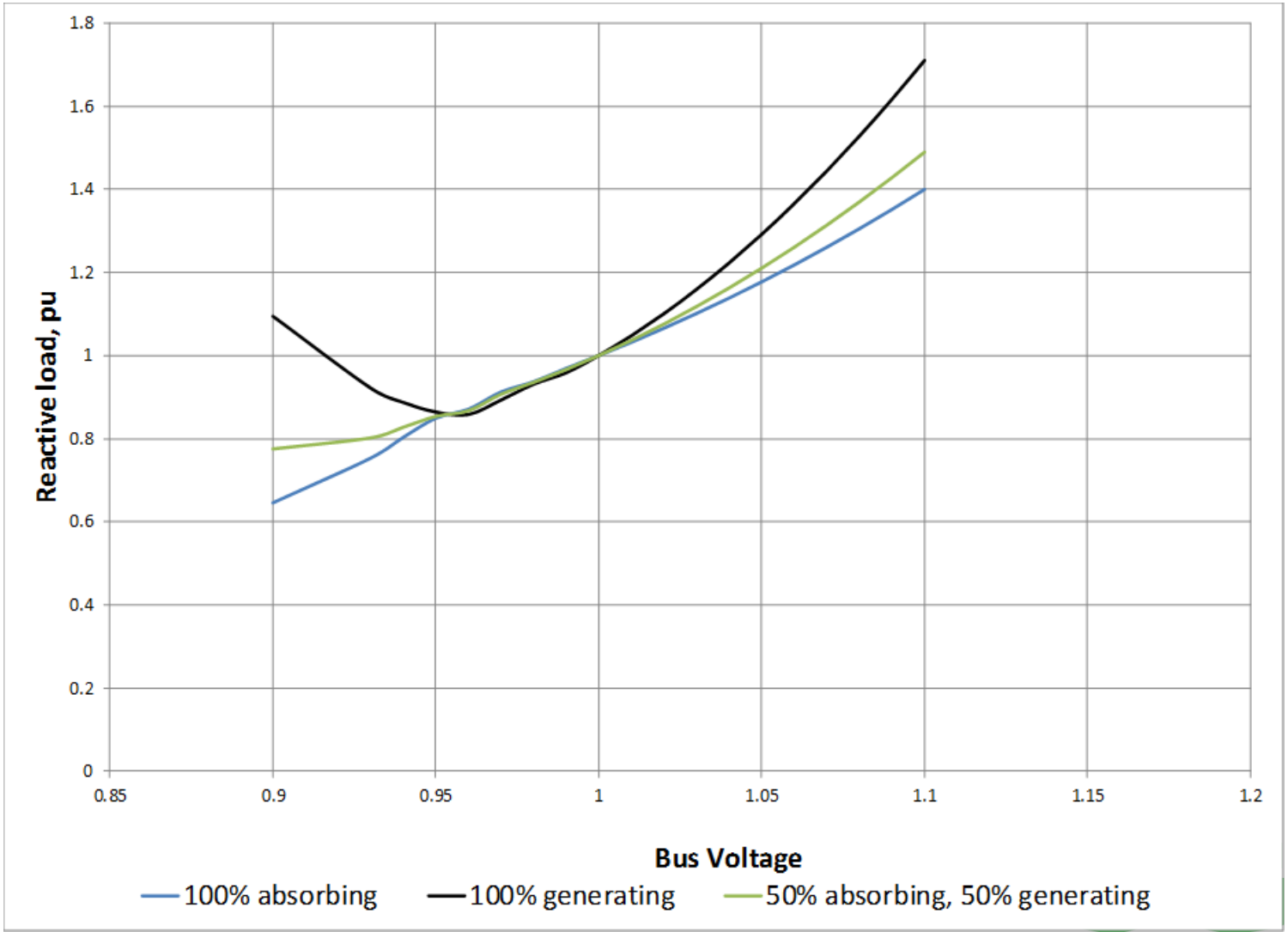


Impact of operating conditions on load-to-voltage dependencies

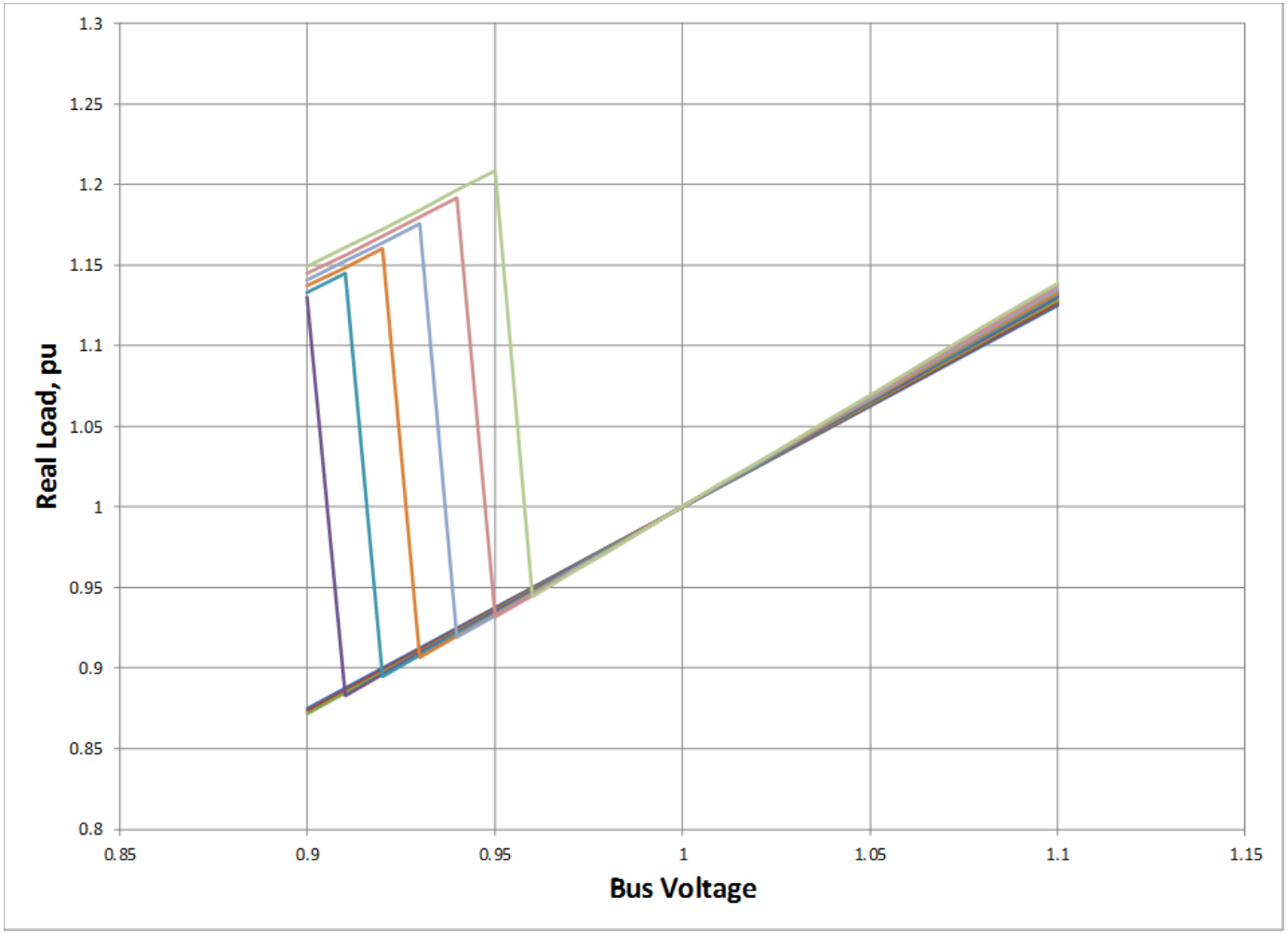
Voltages are different along the feeder. Hence, different voltage ranges of the individual dependencies are used. The reactive load dependencies are different for different injections of real power by the DER.



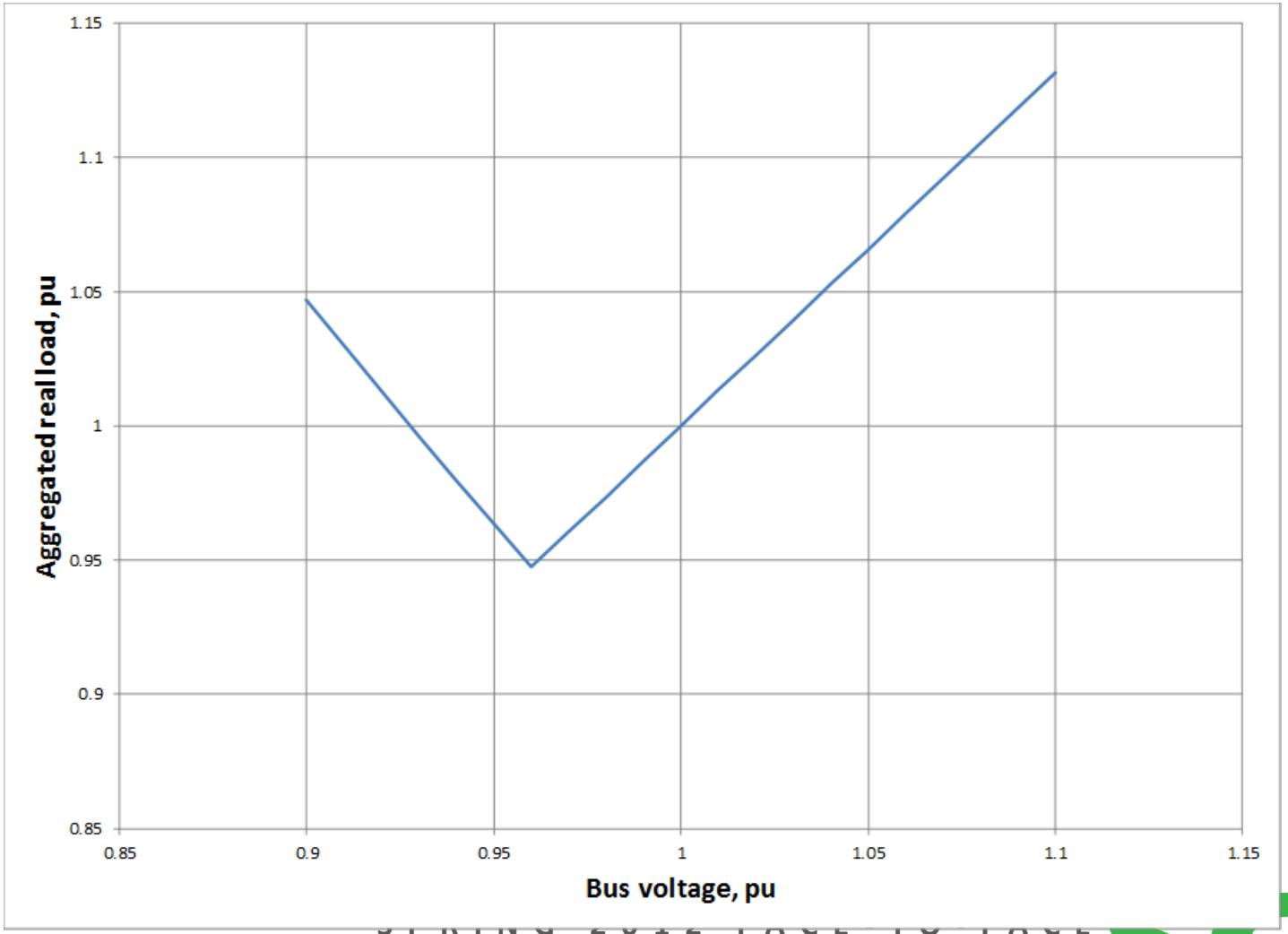
Aggregated at the bus load-to-voltage dependencies.



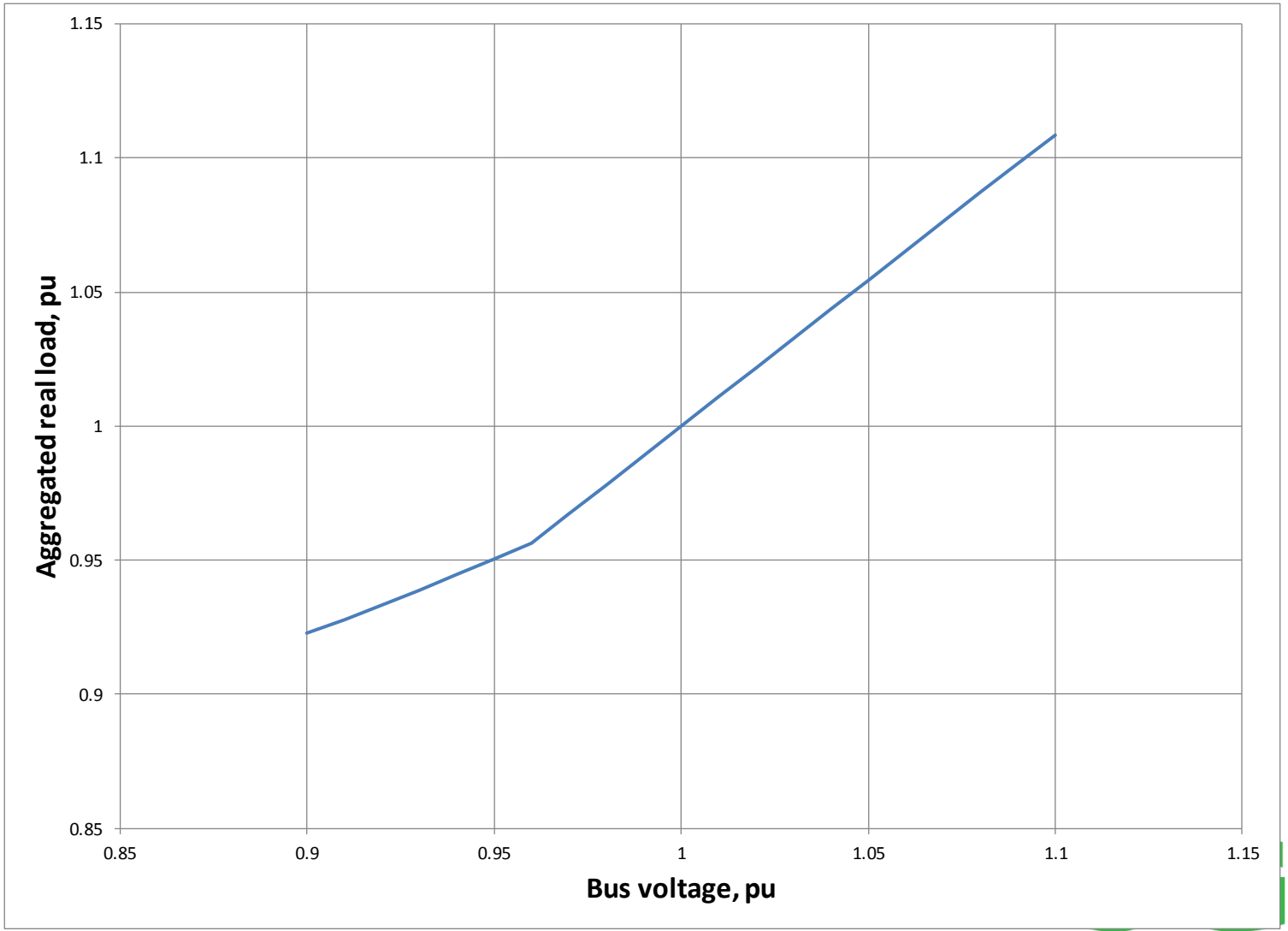
Individual nodal active load dependencies on bus voltage with embedded DER



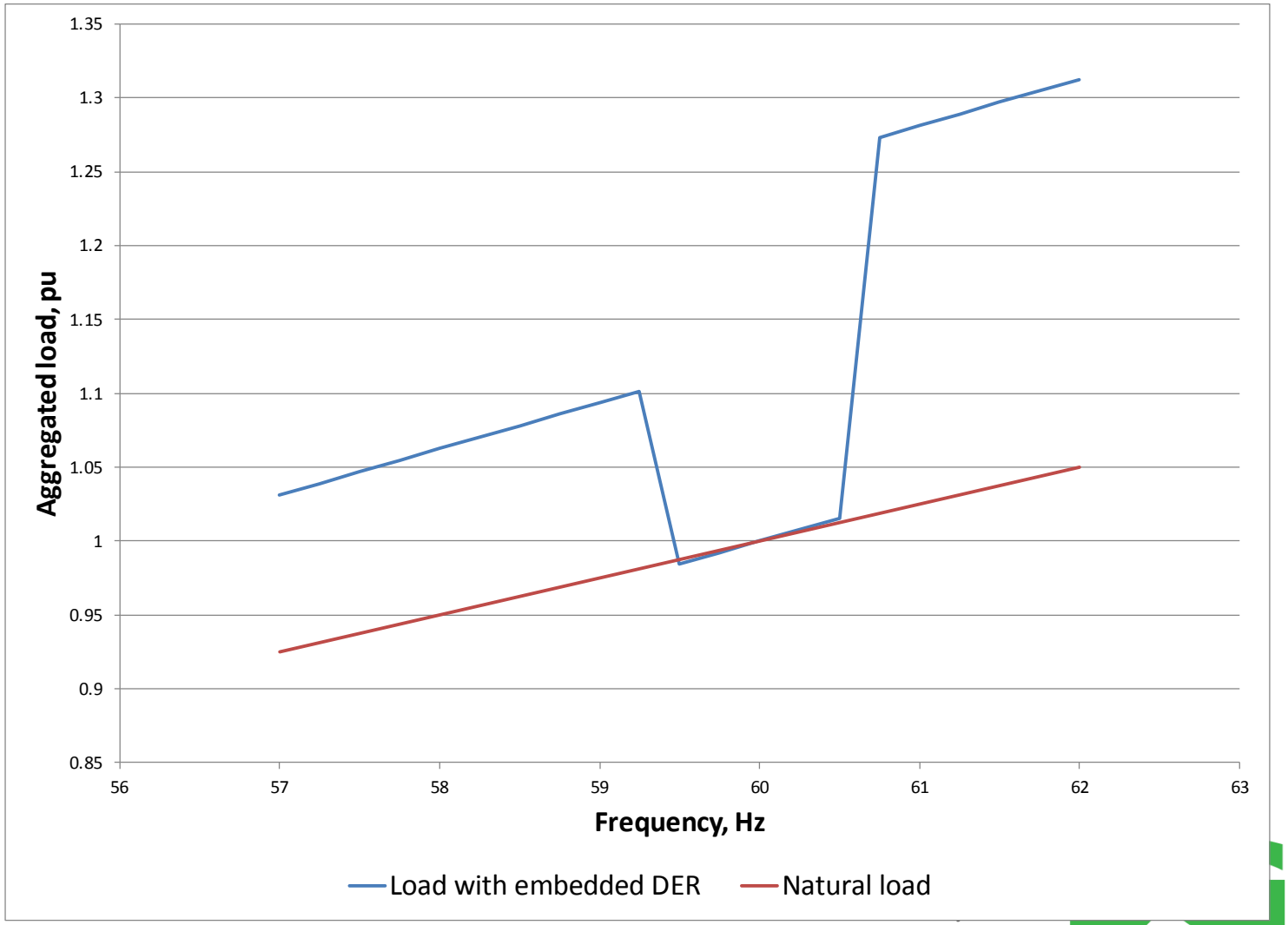
Aggregated at the bus real load-to-voltage dependencies, clear sky



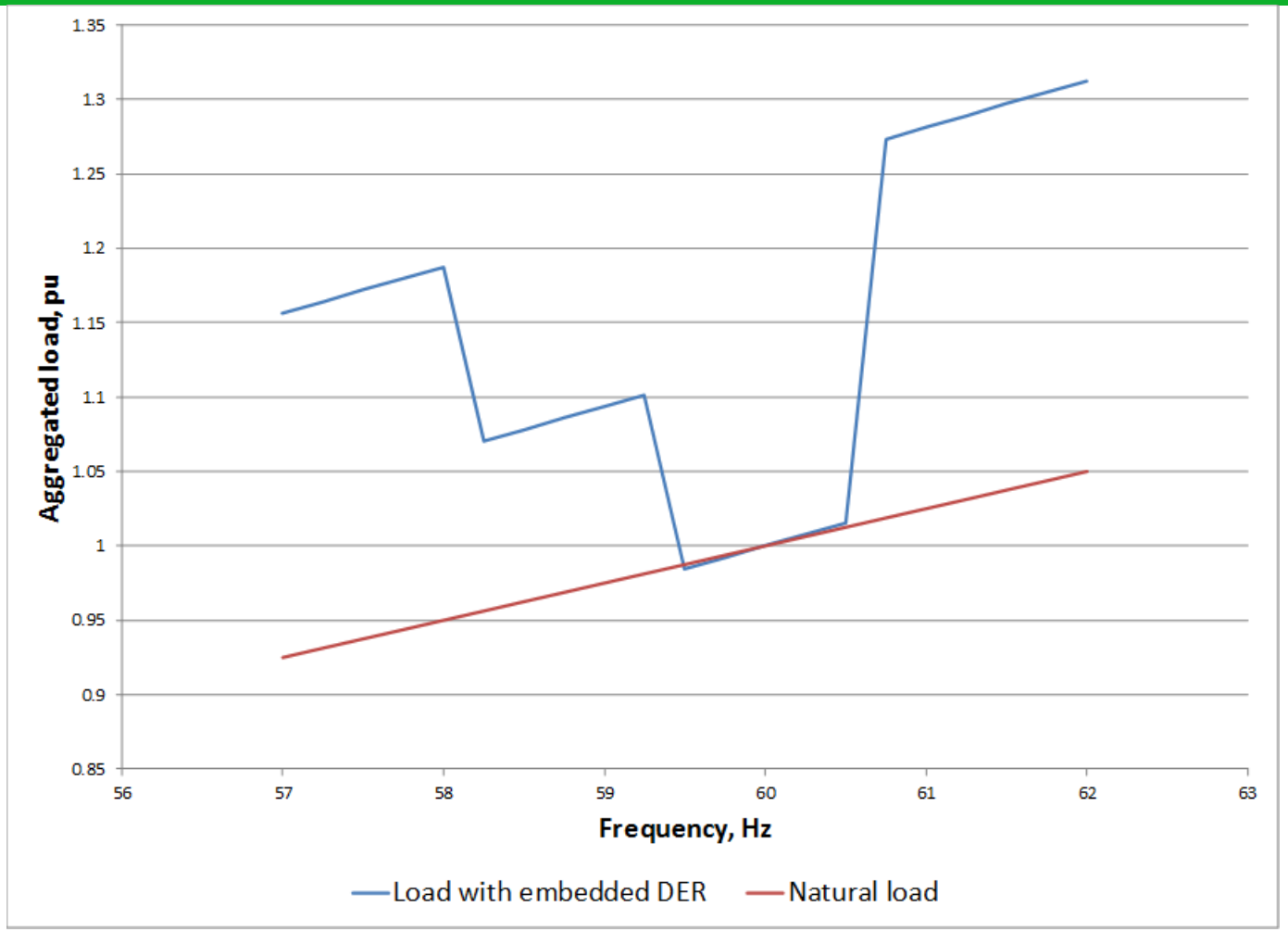
Aggregated at the bus real load-to-voltage dependencies, cloudy sky



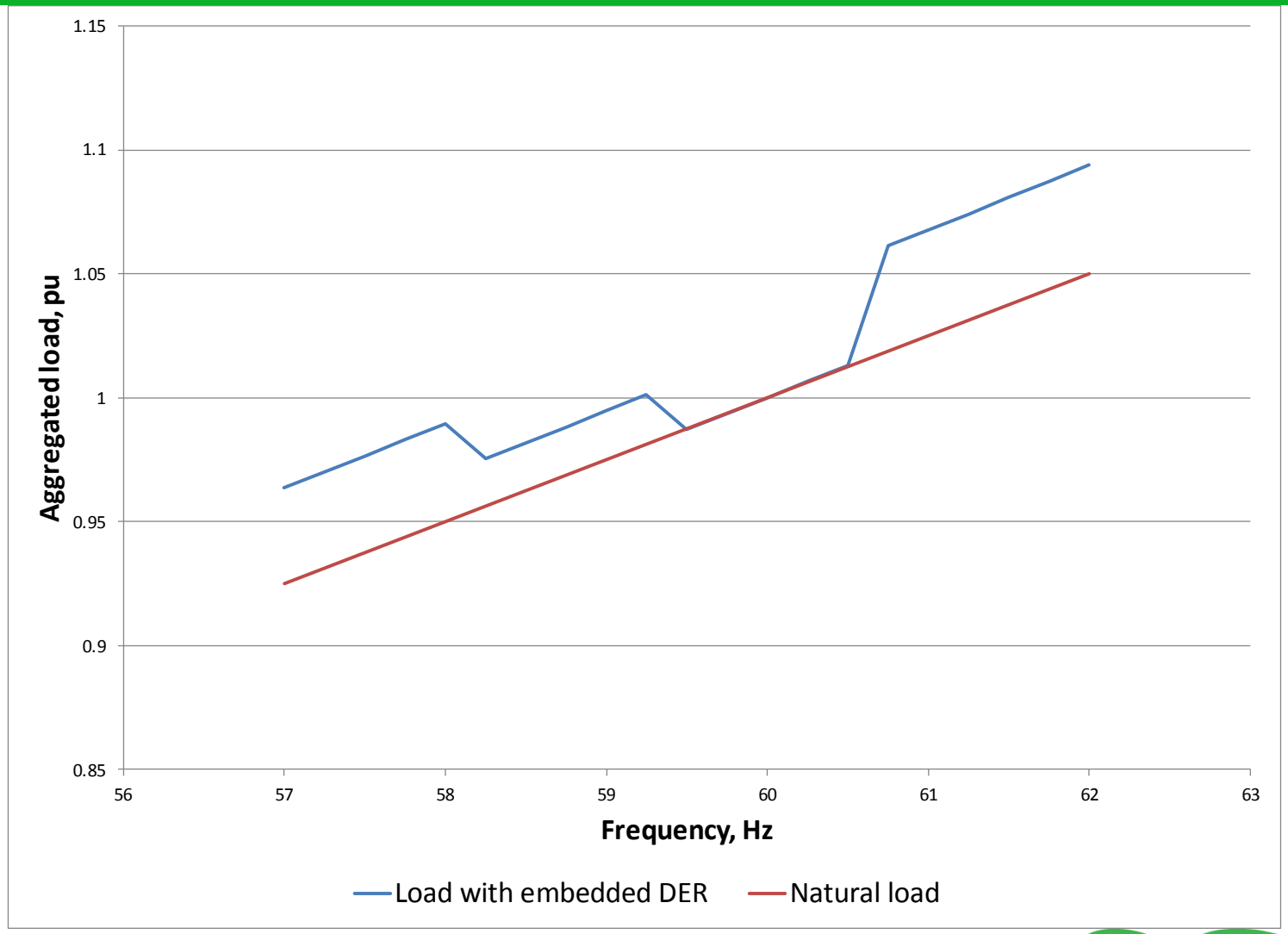
Aggregated at the bus real load-to-frequency dependencies, clear sky, before the time delay for >30 kW



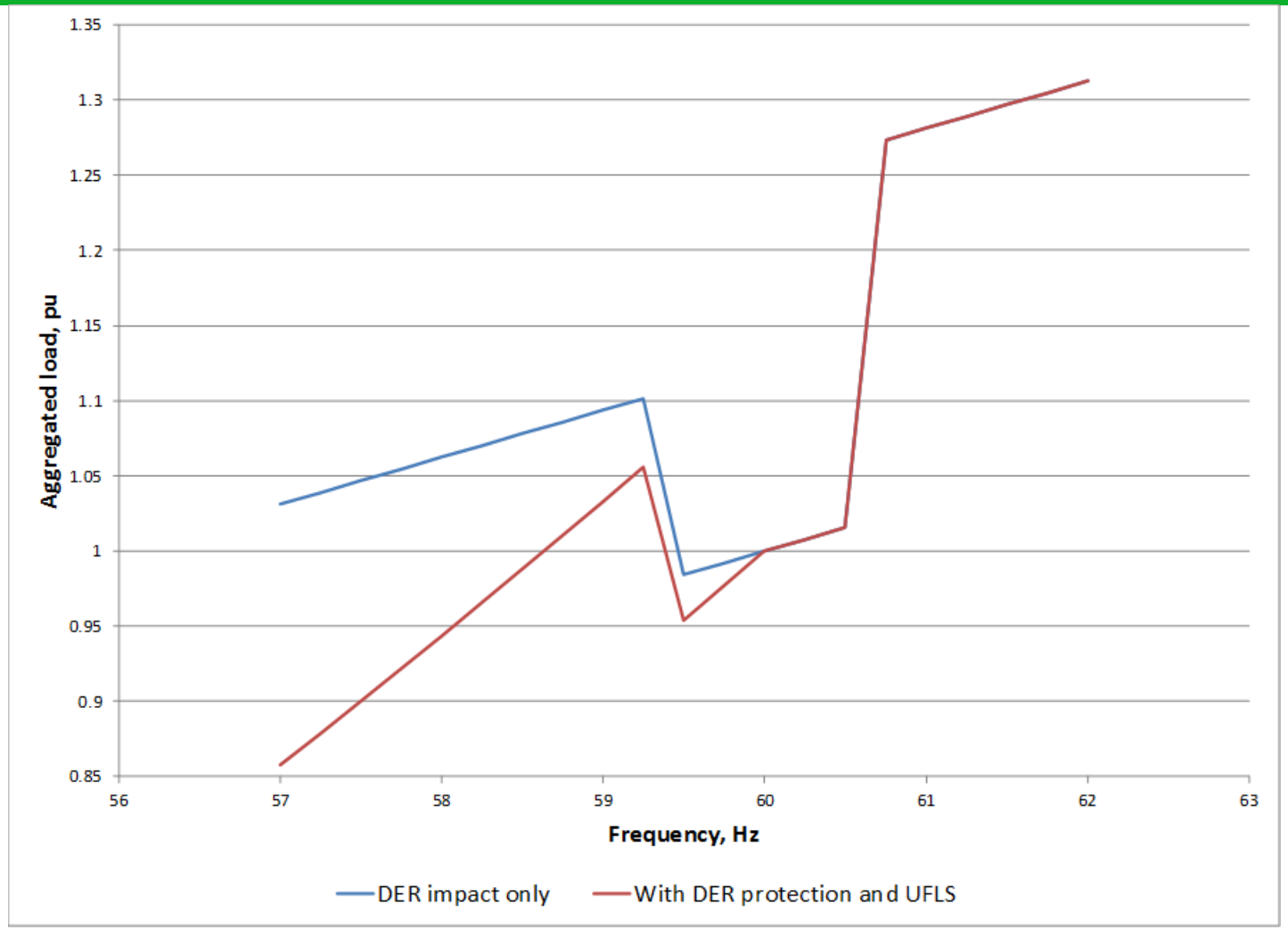
Aggregated at the bus real load-to-frequency dependencies, clear sky, after the time delay for >30 kW



Aggregated at the bus real load-to-frequency dependencies, cloudy sky



Aggregated load dependency on frequency based on DER frequency protection and on the operations of the UFLS



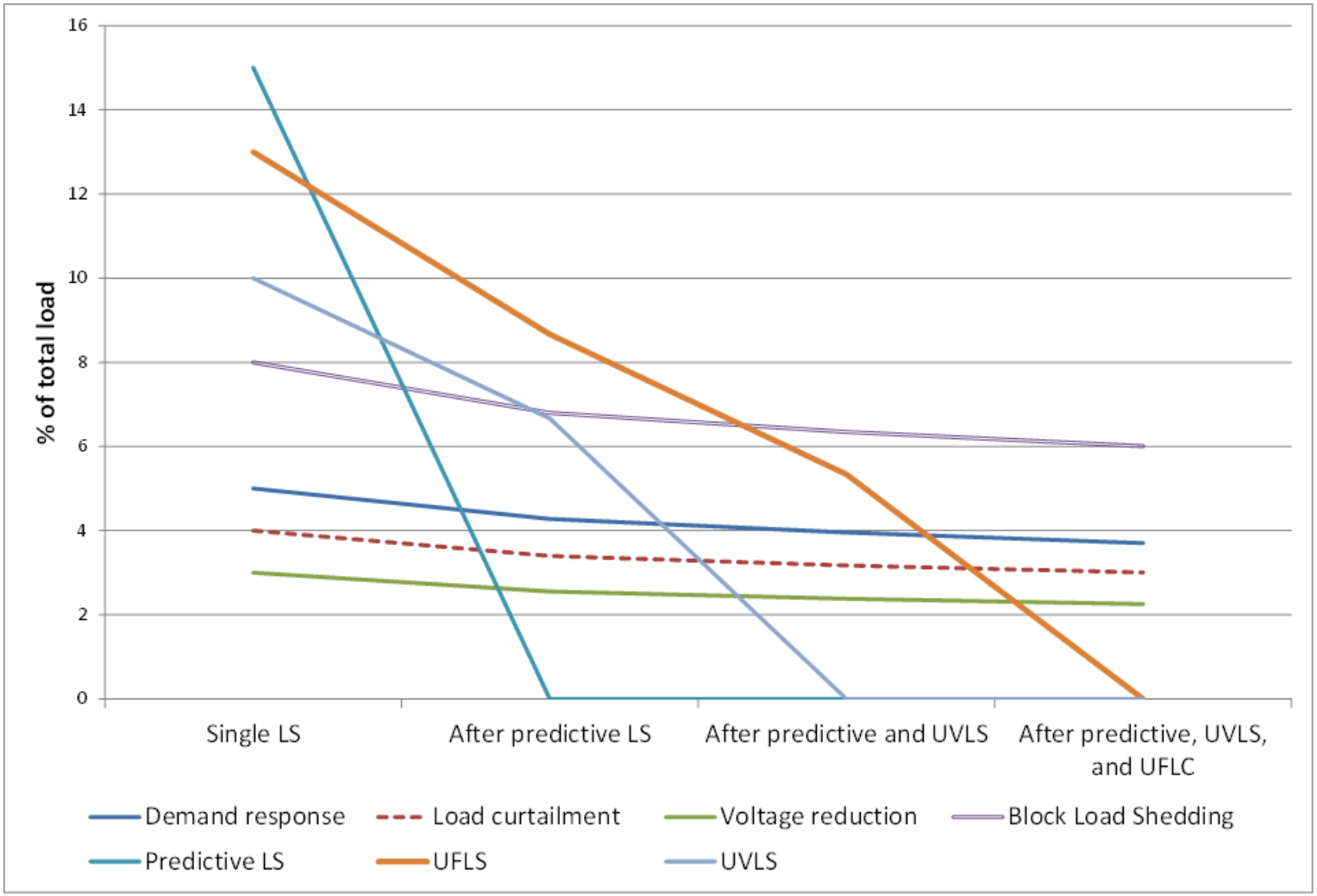
Aggregated Models for Load Management

- The load management can be executed through several programs, such as:
  - Volt/var control in distribution
  - Dynamic pricing
  - Demand response/direct load control
  - Interruptible load/Load curtailment
  - Remedial Actions
    - Under-frequency load shedding
    - Under-voltage load shedding
    - Predictive/special load shedding
    - Block load shedding

The Use of the Load Management Model by EMS

- The least-intrusive load management means can be expected to be used as variables under normal operating conditions
- A more critical use of load management means is a part of the steady-state and dynamic analyses of emergency situations.
- With high penetration of DER in distribution and with the real threat of compromising the cyber security, an exponential growth of the variety of possible emergency situations can be expected.
- This will require an N-m analyses and will also increase the probability of cascading development of emergencies.
- With the high diversity of combinations of contingencies different sequences of load reducing/shedding actions are possible.
- The overlapping of loads among different load management schemes may impact the development of the contingencies.

Effective load shedding capabilities of different load management means in a sequence of execution



Primary Information for the Models of Load Management

- Data models of RAS (IEC 61850)
- Data models of DR, interruptible/curtainable loads, RAS (IEC 61850, ANSI C12x)
- Triggering events:
  - significant change in Demand Response participation (contractual constraints, limited duration, etc.)
  - re-allocation of interruptible /curtailable and block load shedding sites;
  - re-allocation or changes of settings of UFLS, UVLS, Predictive LS, etc.

Other scenarios included in the TBLM Use Case.

- **Develop aggregated models on Demand Response**
  - Provide available aggregated real and reactive Demand Response values, durations, prices, etc., for near-real-time and short-term look-ahead time intervals
- **Develop aggregated real and reactive load dependencies on weather conditions and time**
  - Include the combination of dependencies of natural load, distributed generation and storage, demand response, and the associated impacts of the distribution power flow and DMS applications.
- **Assess the degree of uncertainty of the TBLM (TBD)**

Thank you!

Questions, Comments?